Combination Of The Mottled Waterhyacinth Weevil And The White Amur For Biological Control Of Waterhyacinth[1]

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ABSTRACT

The white amur (*Ctenopharyngodon idella* Valenciennes) and the so-called mottled waterhyacinth weevil (*Neochetina eichhorniae* Warner) were used in combination and alone to test their effects on waterhyacinth [*Eichhornia crassipes* (Mart.) Solms.] contained in plastic pools. The initial combination of 278 to 1,112 g live weight of white amur plus 50 adult weevils per pool for a 10-week period had the greatest negative effect on growth of waterhyacinth, followed by fish alone and weevils alone. White amur apparently did not interfere negatively with weevil activity. The combination reduced the growth of waterhyacinth by 20 to 38% as compared to waterhyacinth plants grown without stress from these organisms.

INTRODUCTION

The white amur and the mottled waterhyacinth weevil are two of the more promising phytophagous animals that are being considered for control of specific aquatic weed problems in Florida (5, 6, 9, 10, 11, 12, 13, 14). The adult white amur is a polyphagous primary consumer (4, 5, 6, 8, 9), whereas the mottled waterhyacinth weevil is obligatorily monoghagous on waterhyacinth[3, 4] (2, 3, 12, 16).

These biological control agents generally attack different parts of a waterhyacinth plant. Small white amur feed mainly on roots of this floating macrophyte, while larger fish feed on pseudolaminae (leaves) as well as roots (1). The mottled waterhyacinth weevil feeds on various plant parts depending on its life stage. Adult weevils feed mainly on pseudolaminae and petioles. Eggs of the weevil are laid in the pseudolamina or petiole, and developing larvae feed as they tunnel downward toward the crown of the plant. Last instar larvae tunnel out of the petiole and construct a cocoon from root hairs. The white amur and the weevil thus can utilize during their feeding all vegetative parts of the waterhyacinth plant. Since both herbivores utilize waterhyacinth roots during their lifetimes, there is potential for some negative interaction at various population levels of all species involved.

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[3]Perkins, B. D. 1972a. Host Specificity and Biology Studies of *Neochetina eichhorniae* Warner, An Insect for the Biological Control of Waterhyacinth. Tech. Rept. U. S. Army Corps of Engineers. 35 pp.

[4]Perkins, B. D. 1972b. Research Leading to Introduction of the First of the Waterhyacinth Insects in the United States. Tech. Rept. U. S. Army Corps of Engineers, Interagency Res. Adv. Comm. Meet., Aquatic Plant Contr. Sect. 7 pp.

Biological weed control with obligatorily phytophagous species offers a potentially viable alternative to widespread use of broad-spectrum herbicides and expensive mechanical or cultural removal methods. The primary objective of biological control of weeds is to achieve a tolerable, stable, anthropocentrically-determined plant density; i.e., to reduce the competitiveness of a particular species so that a mixed plant community of mostly native plants, interacting with their natural enemies, will again be possible. Often a specialized biological agent cannot alone reduce abundance of a weed species sufficiently. In Hawaii, for example, more than 18 different host-specific species of insects have been introduced to combat the weed *Lantana camara* var. *aculeata* (L.) Moldenke.[5] Combining two or more biological agents, however, can result in greater reduction of plant size than use of either agent alone (4). It is unique, however, to use a combination of diverse organisms such as insects and fish. The purposes of this study were to examine the feasibility of using a combination of the mottled waterhyacinth weevil and the white amur to control growth of waterhyacinth, to gauge the effect of seasonality on the degree of control, and to determine possible interaction between the species.

METHODS AND MATERIALS

The following study was replicated during three seasons. Season I (winter) ran from 18 January to 29 March 1974; season II (late spring to summer) from 4 June to 2 August 1974; and season III (late summer to early winter) from 18 November 1974 to 27 January 1975. Twelve circular plastic pools (1.2 m high by 3.1 m in diameter) filled with 5,200 liters of pondwater and with a surface area of ca. 8 m^2 were utilized as experimental containers. For all seasons, 50 waterhyacinth plants with an average initial dry weight per plant of 2.6 g were added to each pool.

Experimental units consisted of combinations of the white amur and mottled waterhyacinth weevil, white amur alone, mottled waterhyacinth weevil alone, and controls (pools without either organism), each replicated with three pools. Two white amur per pool (averaging an initial weight of 556 g) were used in seasons I and II. Due to unavailability of larger fish, three fish per pool, averaging 93 g, were used in season III. Weevil sex ratio was ca. 1:1. Waterhyacinth weevils were added to the pools at the rate of five field-collected (in northern Fort Lauderdale, Florida) adults per plant or 250 individuals per pool. Each experiment was run for 8 to 10 weeks.

To prevent injury to the fish during the weighing process, 10 to 15 mg per liter of Quinaldine®,[6] ($C_6H_4N{:}C(CH_3)CH{:}CH$), a tranquilizer, was added to water in containers used to hold fish immediately after removal from the pools. Fish were normally weighed just prior to being placed in the experimental pools, then again at the end of the experiment. During season I, however, two fish died, were immediately weighed and measured, and were replaced with fresh weighed and measured fish of similar size and age.

Surface measurements of waterhyacinth, i.e. that amount of water surface covered by waterhyacinth, were taken once each week. Water temperatures in the pools and air temperatures above them were taken daily (Monday to Friday) from recording Taylor® maximum-minimum thermometers. Water temperatures were taken at a depth of 38 cm from the surface of the water, which was the vertical midpoint in the water column. Water levels in the pools were adjusted weekly to a predetermined level of 13 cm from the rim of the pool. Pools were fertilized twice during each season (at the start and halfway through each experiment) with ca. 250 g of a soluble commercial formulation of N-P-K in 20-10-15. Plant measurements taken were dry weight, root length, petiole length, pseudolamina width and length, and number of petioles. These measurements were taken initially from 150 plants similar to those placed in the pools and at the termination of each season using 50 plants from each pool. Temperature profiles of the pools were taken midway through, and at the end of season III. Total number of plants was measured initially and at the termination of each season. Also recorded were number of adult weevils, feeding spots and larval tunnels per plant, degree of feeding by white amur on pseudolaminae, presence or absence of the pathogen *Acremonium zonatum* (Saw.) Gams. (which produces zonate leaf spot of waterhyacinth), and miscellaneous undetermined pathogens and saprophytes (including *Cercospora* sp.) which were measured at the end of each season for 50 plants per replicate.

RESULTS AND DISCUSSION

Pools with the combination of the white amur and mottled waterhyacinth weevil generally produced the greatest reduction in plant size and biomass (Table 1). Dry weight per plant, total number of plants, and total waterhyacinth biomass per pool showed this trend in nearly all cases. Controls increased the most (or decreased the least) and the least amount of increase in waterhyacinth biomass occurred in fish plus weevil pools. Statistically significant ($P = 0.05$) differences were shown between replicates (pools) for petiole length and pseudolamina width; between seasons for petiole length and for miscellaneous undetermined saprophytes; between treatments (combinations of agents) for *A. zonatum* damage; and for season by treatment interaction for *A. zonatum* damage. Highly significant ($P = 0.01$) differences were shown between seasons for pseudolamina width and length, total number of plants per pool, total number of petioles per pool, total number of petioles per plant, root length, and *A. zonatum* damage; between treatments for petiole length, pseudolamina width and length, total number of plants per pool, total number of petioles per pool, and root length; and for season by treatment interaction for total number of plants and petioles per pool, and root length. In most cases the fish-

[5]Perkins, B. D. 1966. Status and Relative Importance of Insects Introduced to Combat *Lantana*. Ph.D. Dissertation. Univ. of Hawaii. 178 pp.

[6]Eastman Kodak Co., Rochester, New York 14650. Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the University of Florida or U. S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

TABLE 1. EFFECT OF WHITE AMUR (WA) AND MOTTLED WATERHYACINTH WEEVIL (MW) ON GROWTH OF WATERHYACINTH.

Season-Replicate	Root Length (cm)	Pseudolamina Width (cm)	Pseudolamina Length (cm)	Total No. Petioles/ Plant	Petiole Length (cm)	Dry wt/ Plant (g)	Total No. Plants	Total Dry Wt/Pool (g)
	Percent Change[1, 2]							
I—MW + WA	−69.9 a	−50.4 a	−54.1 abc	3.3 ab	−61.1 ab	−49.2 a	356.7 abc	132.8 a
WA	−58.8 a	−49.1 a	−40.8 d	21.5 bc	−62.0 a	−30.4 ab	580.0 bc	379.5 ab
MW	−26.4 a	−40.9 ab	−44.5 cd	−12.4 a	−49.0 ab	−50.4 a	1,079.3 c	573.9 ab
Control	27.6 bc	−25.5 bcd	−23.3 e	5.5 ab	−44.1 b	−26.7 ab	2,334.0 e	1,694.9 d
II—MW + WA	−76.7 a	− 6.2 cde	−41.6 abc	32.2 cde	−34.2 ab	−25.7 bc	388.0 abc	397.6 ab
WA	−80.1 a	− 2.5 de	−41.2 abc	32.5 cde	−44.6 ab	−11.2 bc	258.0 ab	214.2 a
MW	− 9.1 c	− 9.9 cde	−32.9 bcd	28.0 cd	−29.5 ab	6.5 cd	700.7 cd	809.2 bc
Control	56.6 d	− 0.6 e	−22.1 d	45.8 def	− 1.7 c	100.0 e	572.0 bc	1,279.4 cd
III—MW + WA	−39.7 a	−23.5 bc	−31.0 a	47.7 ef	−38.8 ab	−12.7 bc	31.3 a	13.7 a
WA	−24.7 a	− 9.7 cde	−23.4 ab	50.6 f	−39.3 ab	−13.1 bc	93.3 ab	66.9 a
MW	37.7 ab	−12.8 cde	−39.6 a	40.8 def	−33.0 ab	9.0 cd	49.3 a	64.6 a
Control	142.7 c	− 1.9 e	−18.5 ab	31.2 def	−33.6 ab	35.1 d	104.7 ab	173.1 a

[1]Percent change $= \frac{(\text{Initial} - \text{Final})}{\text{Initial}} \text{X } 100.$

[2]Values in the same column followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test (7).

weevil combination had the greatest decrease or least increase, usually followed by fish alone, weevils alone, and controls.

Weights and measurements of fish increased from start to end in all seasons but the first (Table 2). Individual differences in age, health status and food differences prior to testing may have contributed to season I results.

Damage to waterhyacinth by white amur and weevils was also generally greater with the agents in combination than with either agent alone (Table 3). Statistically sigsignificant differences were shown between seasons for of weevil larval tunnels, and between treatments for percent of pseudolaminae eaten by the white amur. Highly significant differences were shown between season for weevil feeding spots per pool, and between treatments for weevil larval tunnels, feeding spots, and adults per pool.

Average monthly water temperatures for each season were usually different between treatments. Generally, control pools contained the highest water temperatures each season, usually followed by weevil-alone pools, fish plus weevil pools, and fish-alone pools. Depth profiles of all treatments indicated that the drop in temperature per 10 cm depth was 0.05 C for the first 20 cm and 0.03 for the last 50 to 60 cm for weevil-alone pools; 0.07 and 0.03, respectively, for fish-alone pools; 0.05 and 0.04, respectively, for fish plus weevil pools; and 0.07 and 0.04, respectively, for controls. These data indicate that presence of white amur, which mix the warm surface water with cooler water below, created a more even temperature gradient in our pools. An increase in turbidity was also noted in fish pools, which may also have contributed to lower temperatures in those pools. This temperature-turbidity effect will be further considered when this experiment is conducted under field conditions.

Plants in control pools generally increased the most in surface area at the end of each season, while fish plus weevil pools decreased the most or increased the least in waterhyacinth biomass, followed by fish-alone and weevil-alone pools.

In general, considering all measured parameters, the combination of the mottled waterhyacinth weevil and the white amur had the greatest damaging effect on water-

TABLE 2. AVERAGE WEIGHTS AND MEASUREMENTS OF WHITE AMUR (WA) CONTAINED IN POOLS ALONE AND IN COMBINATION WITH MOTTLED WATERHYACINTH WEEVILS (MW) FOR CONTROL OF WATERHYACINTH.

Treatment-	Season	Standard Length (cm)			Body Depth (cm)			Weight (g)		
		Initial	Final	% Change[a]	Initial	Final	% Change	Initial	Final	% Change
MW + WA	I[a]	305.6	304.6[d]	−0.3	73.4	69.0	−6.0	531.8	466.8	−12.2
	II[b]	305.8	310.5	1.5	72.0	80.5	11.8	580.6	632.2	8.9
	III[c]	162.6	174.9	7.6	41.4	45.1	8.9	92.7	113.8	22.7
WA alone	I	317.7	304.6	−4.1	73.0	67.8	−7.1	559.5	530.9	−5.1
	II	327.2	332.8	1.7	68.5	76.0	11.0	591.8	622.1	5.1
	III	160.6	169.9	5.8	41.1	41.8	1.6	91.0	104.5	14.8

[a]Percent change $= \frac{(\text{Initial - Final})}{\text{Initial}} \text{X } 100.$

[b]Two fish per pool.
[c]Three fish per pool.
[d]One fish each died on 6 Feb. 1974 and 25 Feb. 1974; both were replaced with other fish of similar age and size.

TABLE 3. NUMBER OF ADULT MOTTLED WATERHYACINTH WEEVILS (MW), AND DAMAGE CAUSED BY ADULT AND LARVAL WEEVILS AND WHITE AMUR (WA) ON WATERHYACINTH PER POOL.[a]

Season-Replicate	No. Adult MW	No.MW Larval Tunnels	No. MW Feeding Spots	WA Damage	
				No. Leaves Attacked	Leaves Eaten (%)
I—MW + WA	12.6 a	941.1 a	17,356.3 b	—[b]	—[b]
WA	1.9 a	0.0 a	350.8 ab	—[b]	—[b]
MW	68.6 b	2,716.9 b	42,596.9 c	—[b]	—[b]
Control	0.0 a	0.0 a	0.0 a	—[b]	—[b]
II—MW + WA	89.4 b	757.5 a	36,232.9 c	188.2 a	36.6 a
WA	0.0 a	0.0 a	80.1 a	—[c]	—[c]
MW	59.9 ab	871.7 a	4,769.4 c	383.8 b	73.8 a
Control	0.0 a	5.8 a	440.6 ab	—[c]	—[c]
III—MW + WA	81.3 b	77.8 a	9,492.0 ab	280.0 a	82.4 a
WA	2.5 a	0.0 a	444.9 ab	—[c]	—[c]
MW	46.4 ab	236.9 a	13,269.0 ab	266.3 a	67.3 a
Control	0.0 a	0.0 a	532.2 ab	—[c]	—[c]

[a]Values in the same column followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test (7).
[b]Measurements not recorded.
[c]Pool without fish.

hyacinth growth and general health condition, followed by fish-alone, weevils-alone, and controls.

Waterhyacinth is not one of the favored aquatic weeds that white amur will select in a mixed-culture field situation (4, 10, 14). This experiment shows, however, that the white amur will eat waterhyacinth if it exists in a nearly monoculture situation, as is the case in many lakes and canals in Florida. The mottled waterhyacinth weevil is well established in southern Florida, and the equally-monophagous so-called chevroned waterhyacinth weevil (*N. bruchi* Hustache) was first released on waterhyacinth in southern Florida in 1974. Other species of insects are slated for release in Florida for the biological control of waterhyacinth (2, 11, 12, 13). All these insects, however, plus the waterhyacinth mite (*Orthogalumna terebrantis* Wallwork), attack only waterhyacinth. The addition of the white amur in carefully-selected field sites will add another factor to be considered in biological control programs of hydrophytes. Evaluation of the efficacy in natural situations of these several biological control agents will help determine limits of use of fish and insects in combination to control aquatic macrophytes.

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